Presented in the ECWC 10 Conference at IPC Printed
Circuits Expo®, SMEMA Council APEX® and
Designers Summit 05

Application of Thermography and Holography to Thermal Stress Evaluation of Printed Circuit Board

Takanori Netsu, Kazuhiro Kameyama, Toshiaki Yanada
Masanari Taniguchi and Tasuku Takagi
Tohoku Bunka Gakuen University
Sendai, Japan

Noriyoshi Chubachi
Tohoku Gakuin University
Tagajyo, Japan

Abstract
The comparison of the thermal pattern and the deformation pattern both are obtained on the surface of Printed Circuit Board (PCB) was done to understand how both patterns correspond to each other. In the present study, both the FEMLAB simulator and Thermography were employed for the study.

A Holographic Pattern Measuring System (HPMS) and an Interferometry Imaging System (IMS) were used. The test results showed that both thermal pattern and deformation pattern were different from each other. We found that we could not deduce the thermal deformed pattern on a PCB from its thermal pattern.

Introduction

Due to recent trends toward miniaturization and high density packaging in printed circuit board (PCB)[1, 2] and a high level current flows through PCB line and contacts, the PCB is often affected by thermal stress with Joule heat due to current flow through fine circuit line and/or mounted parts.[3-5] The thermal stress deforms the PCB and/or connector mounted on the PCB which can closely relate to the contact failures.[6-9]

The evaluation of thermal deformation in PCBs has become important in a context of reliability of electronic system. The simulation technique or thermography has been used as the usual method to evaluate thermally stressed PCBs.[11, 12]

The authors developed a new measuring system (Holographic Pattern Measuring System: HPMS) for the thermal deformation analysis. The HPMS is composed of the system comprised of both techniques of holographic interferometry and graphic image processor.[12, 13]

In this study, by applying both FEMLAB simulator and Thermal Graphic Measuring System (TGMS: Thermography), the thermal pattern was analyzed of PCB. In addition, the deformation pattern was measured by the HPMS.

Test Sample of PCB and Thermal Pattern

Test Sample

Figure 1 shows the test sample of PCB and experimental set-up. As shown in Figure 1, the three resistors (100Ω,1/4W) and one IC (SN7400) are mounted on the PCB surface. The material of the test sample of PCB is paper epoxy resin, of which size was 80x55 mm, and thick ness 1.6 mm.

The heat was imposed as the thermal stress to the PCB by the Joule heat originating from the mounted parts due to current flow.

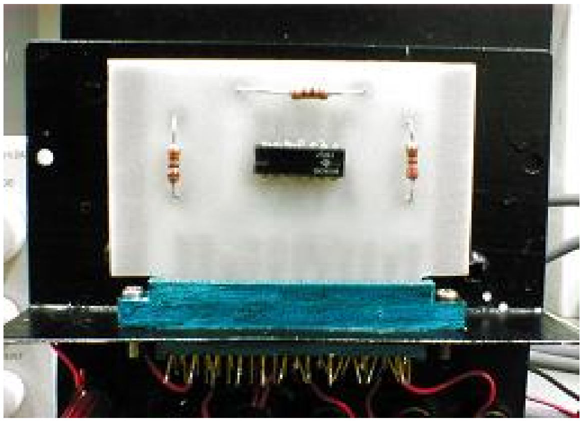


Figure 1 – Test Sample of PCB and Mounted Devices

Thermal Pattern by using FEMLA

Figure 2 shows a model of PCB surface for simulation by using FEMLAB which is the simulation software. In the simulation, the thermal pattern of PCB surface was calculated in case where the current of 400mA DC flowed through the mounted three resistors.

Figure 3 shows an example of computed thermal pattern in case after 240 sec of the current switched off. And, Figure 4 shows the relationship between the current flow time and temperature on the resistor surface.

As shown in Figure 3, the high temperature was observed in the center of mounted resistor. And, as shown in Figure 4, the maximum temperature was about 50 °C after a current flow of 30 sec.

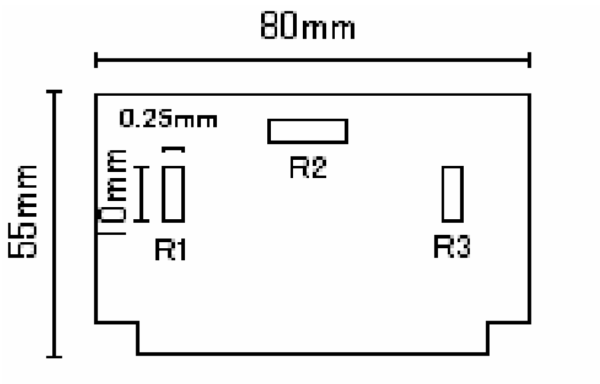


Figure 2 – Model of PCB surface for Simulation

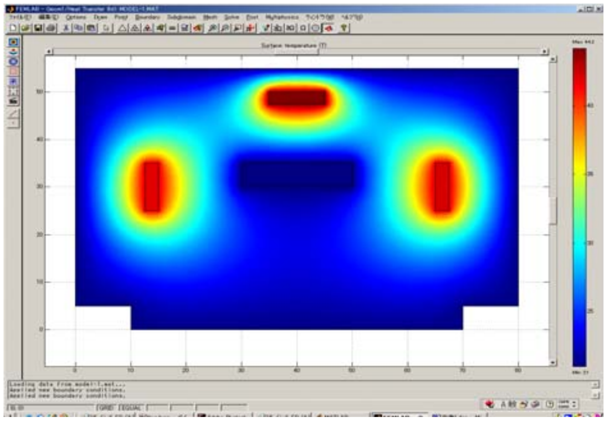


Figure 3 – Thermal Pattern on PCB Surface by using FEMLAB

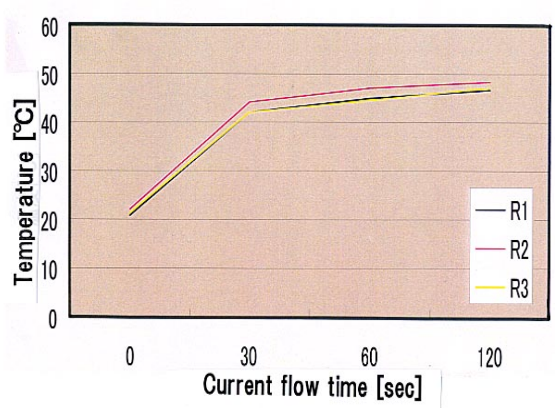


Figure 4 – The Relationship between the Current Flow Time and Temperature on the Resistor Surface

Thermal Pattern by using Thermography

In the experiment, the thermal image measurement system (Thermography: NEC TH3104MR) shown in Figure 5 was used.

Figure 6 shows the thermal pattern on PCB surface by using thermography due to current (400mA DC) flowing through the mounted resistors for current flow times of 30 sec and 240 sec, respectively. Figure 7 shows the relationship between the current flow time and temperature on the resistor surface.

As shown in Figure 6, the thermal pattern was observed in center of mounted resistor, which is the same pattern calculated by FEMLAB, however patterns were also observed at the soldering joints. And, as shown in Figure 7, the temperature on resistor surfaces increased rapidly and saturated as the current flow time increased. The maximum temperature was observed about 50 °C.

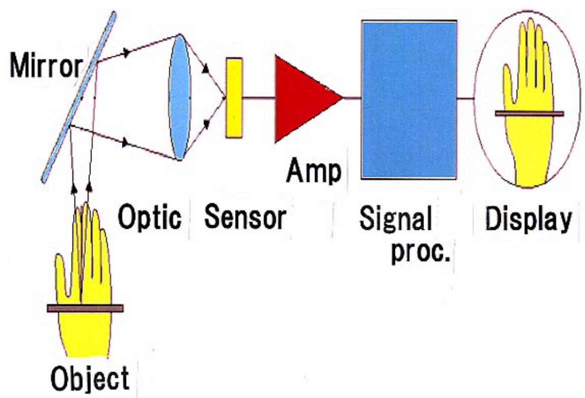
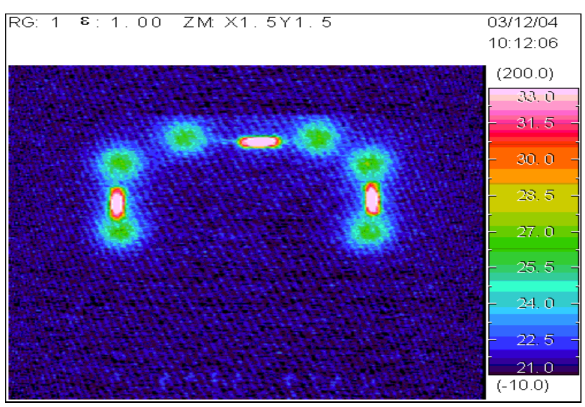
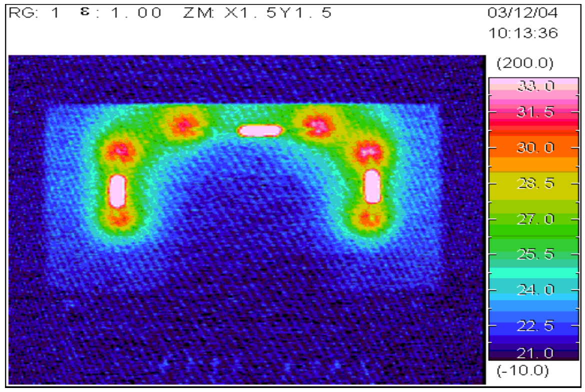


Figure 5 – Schematic Diagram of Thermal Image Measurement System



(a) after current flow time 30 sec



(b) after current flow time 240 sec

Figure 6 – Thermal pattern of PCB Surface by using Thermograpy

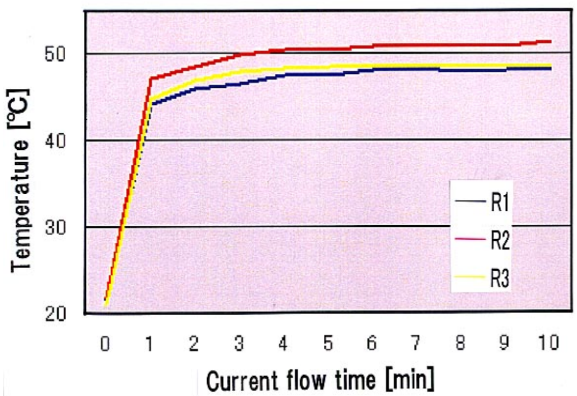


Figure 7 – The Relationship between the Current Flow Time and Temperature on the Resistor Surface

Deformation Pattern by using HPMS

Holographic Pattern Measuring System (HPMS)

The HPMS is composed of both techniques of holography and graphic image processing. Figure 8 shows the schematic diagram of interferometry measuring system (IMS). In this measuring system, the double exposure method (DEM) was used to detect deformation pattern of PCB surface.

By using DEM, the original image of the PCB is observed with an interference fringe line that corresponds to the displacement. Then, the displacement level of PCB surface can be calculated from the distance between adjacent two fringe lines, which is approximately $\lambda/2$ where λ denotes the wave length of the laser.[13]

By using the graphic image processing system, the distribution of displacement is calculated from the sampled data of fringe pattern, and, its 3-dimensional graphic image is displayed on a CRT which is plotted out by means of the wire-frame method.

In order to obtain the smooth wire-frame curve line from a small data sample, the cubic spline function was applied.

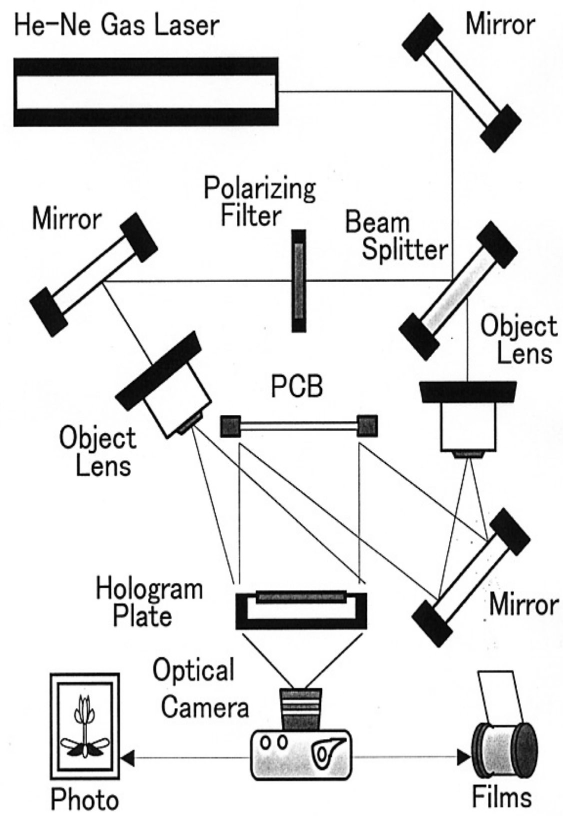
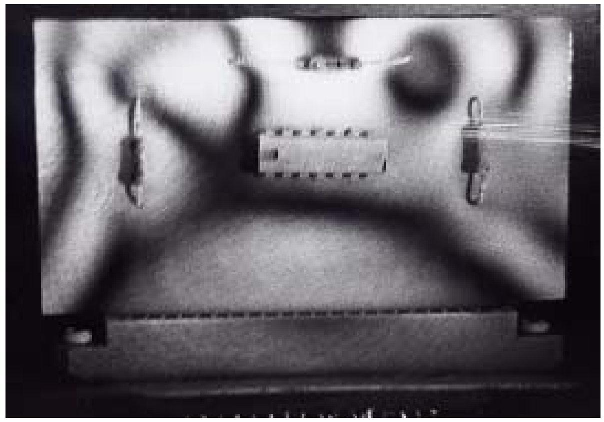


Figure 8 – Schematic Diagram of Holographic Interferometry Measuring System

Deformation Pattern by using IMS

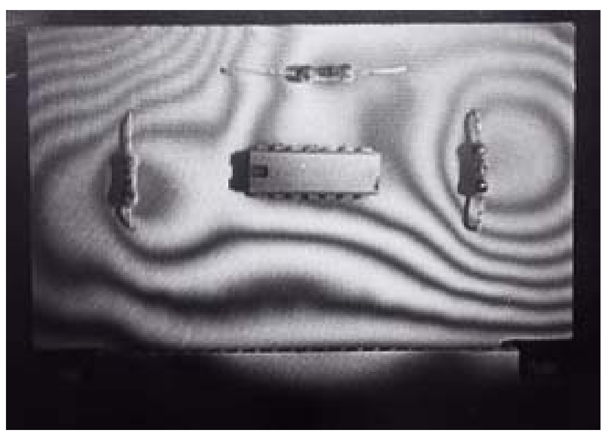
Examples of the reconstructed interferogram of PCB due to current flowed through the mounted resistors are shown in Figure 9 in case of the current flow time 10 sec, 60 sec and 240 sec, respectively.

As shown in Figure 9, the number of fringe lines increased with the increase of current flow time. At the same time, the fringe pattern on the PCB surface was also observed at the mounted resistors on both sides.



(a) after current flow time 10 sec .

(b) after current flow time 60 sec.



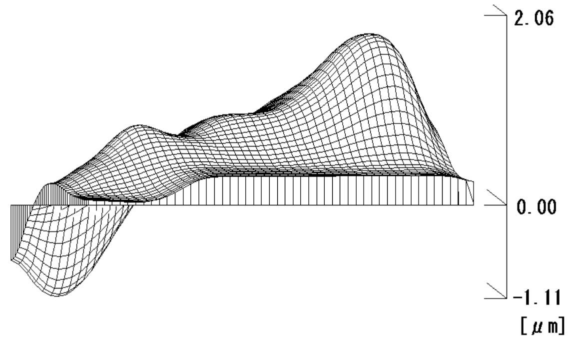
(c) after current flow time 240 sec.

Figure 9 – Holographic Interferogram of PCB Surface Due to Thermal Stress

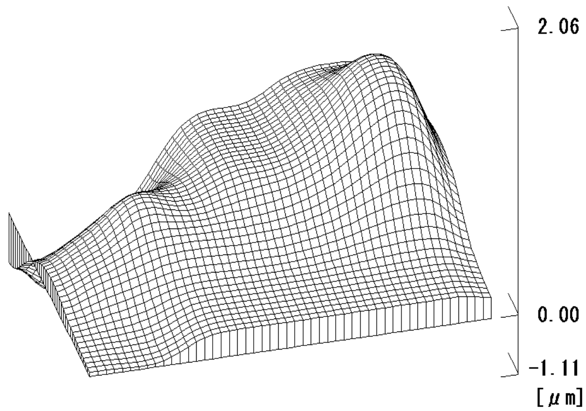
3-D of PCB Surface Deformation Pattern

The examples of the 3-dimentional graphic image of displacement of PCB surface are shown in Figure 10, which are calculated from the fringe pattern shown in Figure 9(a).

As shown in Figure 10, the whole sections of the PCB bend smoothly as a result of thermal stress. The maximum level of displacement was about 3 μm which increases with increase of the current flow time. The deformation pattern image could be clearly obtained as the 3-D graphic image.



(a) in case observed from under side



(b) in case observed from oblique side

Figure 10 – 3-D Graphic Image Deformation Pattern of PCB Surface Due to Thermal Stress

Conclusions

In this study, the thermal image measuring system and FEMLAB simulation technique were tested for qualitative evaluation the deformation of PCB surface due to thermal stress, comparing the quantitative measurement of microscopic displacement and its 3-D graphic image using the Holographic Measuring System (HPMS) and Interferometry Measuring System (IMS).

We found from the comparison that we could not image the deformation pattern from the thermal pattern because both patterns are quite different each other. Thus in order to analyze the deformation of PCB, we conclude that the HPMS is the one of the best methods for such proposes

References

1. H.Hayashi: "Criteria for Electronic Packaging Technology as Driver in Future", Proc. of ECWC, M2-4, (Sep. 1999)
2. C.E.Bauer: "Packaging MEMS, the Great Challenge of the 21st Century", Proc. of IEMT/IMC Symp. pp.239-243, (Apr. 2000)
3. D.S.De Lorenzo: "Thermal Design of High-Density Server", IEEE Trans. on CPMT, 25(4), pp.635-640, (Dec. 2002)
4. D.L.DeVoe: "Thermal Issues in MEMES and Micro-scalel Systems", IEEE Trans. on VPMT, 25(4), pp.576-583, (Dec. 2002)
5. J.H.Parry, J.Rantala, and C.J.M.Lance: "Enhanced Electronic System Reliability –Challenges for Temperature Prediction", IEEE Trans. on CPMT, 25(4), pp. 533-538, (Dec. 2002)
6. D.M.Stubbs, S.H.Pulko and A.James:" An Investigation of the Sensitivity of Embedded Passive Component Temperatures to PCB Structure", IEEE Trans. on CPMT, 25(4), pp.701-707, (Dec. 2002)
7. G.Norberg, S.Dejanovic and H.Hesselbom: "Elastomer Chip Sockets for Reduced Thermal Mismatch Problems an Effortless Chip Replacement, Preliminary Investigations", IEEE Trans. on CPMT, 26(1), pp.33-40, (Feb. 2003)
8. V.Szekely and M.Rencz: "Increasing the Accuracy of Thermal Transient Measurements", IEEE Trans. on CPMT, 25(4), pp.539-546, (Dec. 2002)
9. K-H.Kim, Y-W.Huang, K.L.Chua and T.B.Lim: "Effect of Underfill and Die Geometry on Thermal Shock and Moisture Resistance Test Performance for Flip Chip PBGA", Proc. of IEMT/IMC Symp. pp.291-296, (Apr. 2000)

10. M.Rencz, V.Szekely, Zs.Kohari and B.Courtois: ”Thermal Evaluation and Modeling of MEMS Packages”, Proc. of IEMT/IMC Symp. pp.326-331, (Apr. 2000)
11. H.Ding, R.E.Powell, C.R.Hanna and C.Ume: ”Warpage Measurement Comparison Using Shadow Moire and Projection Moire Methods”, IEEE Trans. on CPMT, 25(4), pp.714-721, (Dec. 2002)
12. M.Taniguchi and T.Takagi: ”Variation of Contact Resistance of Contacts Mounted on Printed Circuit Board Due to Thermal Deformation Observed by Holographic Technology”, Proc. of IEMT/IMC Symp pp.432-437, (Apr. 2000)
13. M.Taniguchi and T.Takagi: “Thermal Deformation Analysis of printed Circuit Connector Due to Current Flow by Using Holography”, Proc. of IEMT/IMC Symp., pp.336-341, (Apr. 1999)
14. C.M.Vest: "Holographic Interferometry", John Wiley & Sons, (1979)

ECWC 10 in Anaheim, California, U.S.A. [Feb. 22-24, 2005]

Application of Thermography and Holography to Thermal Stress Evaluation of Printed Circuit Board

Takanori NETHU*, Kazuhiro KAMEYAMA*, Masanari TANIGUCHI*,

Tasuku TAKAGI*, Norifumi CHUBACHI**

* Tohoku Bunka Gakuen University, Sendai, Japan

** Tohoku Gakuin University, Tagajo, Japan

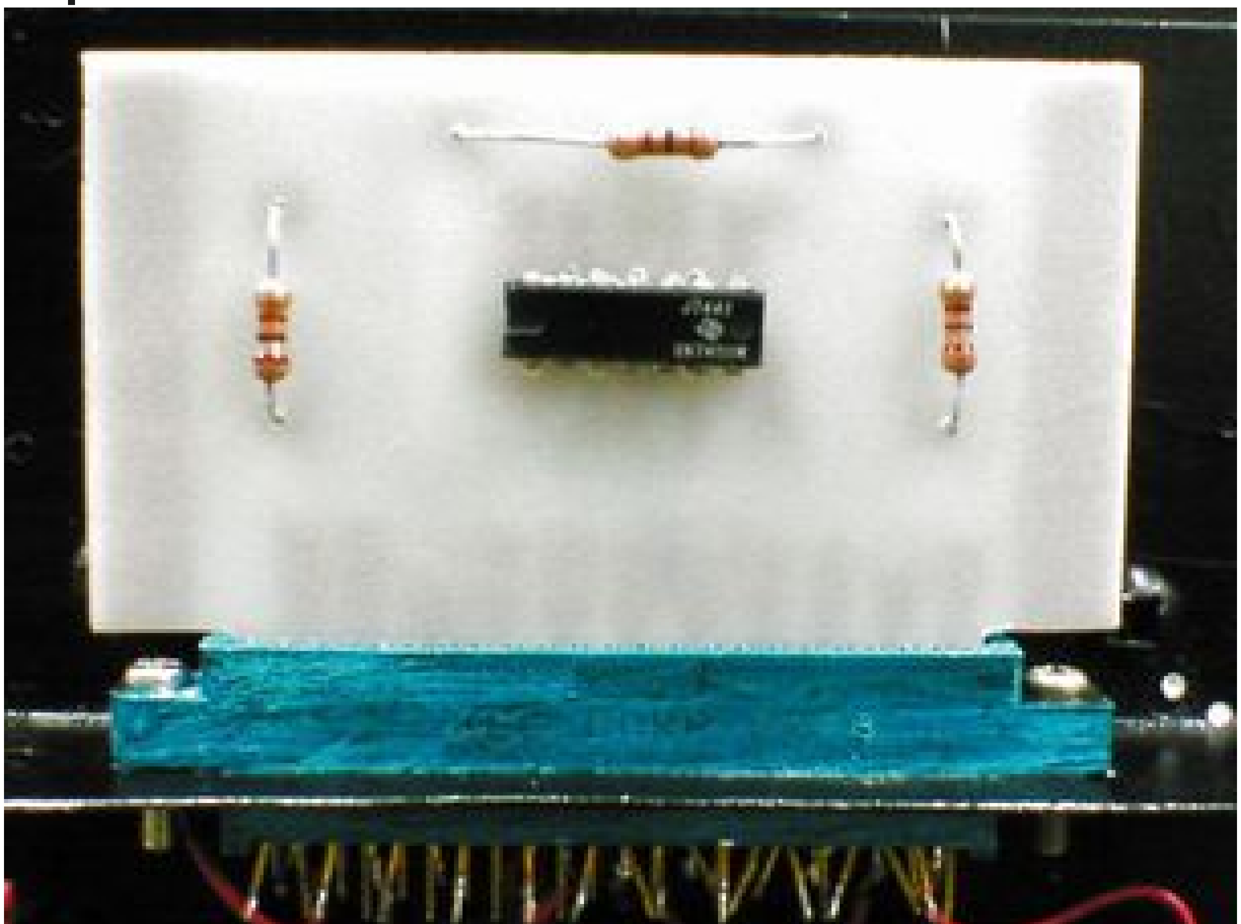
Background

Due to recent trends toward miniaturization and high density packaging in printed circuit board (PCB), and a high level current flows through PCB line and contacts, the PCB is often affected by a thermal stress with the Joule's heat due to current flow through fine circuit line and/or mounted parts.

Thermal stress deforms the PCB and/or connecter mounted on the PCB which causes the contact failures may occur from the thermal deformation.

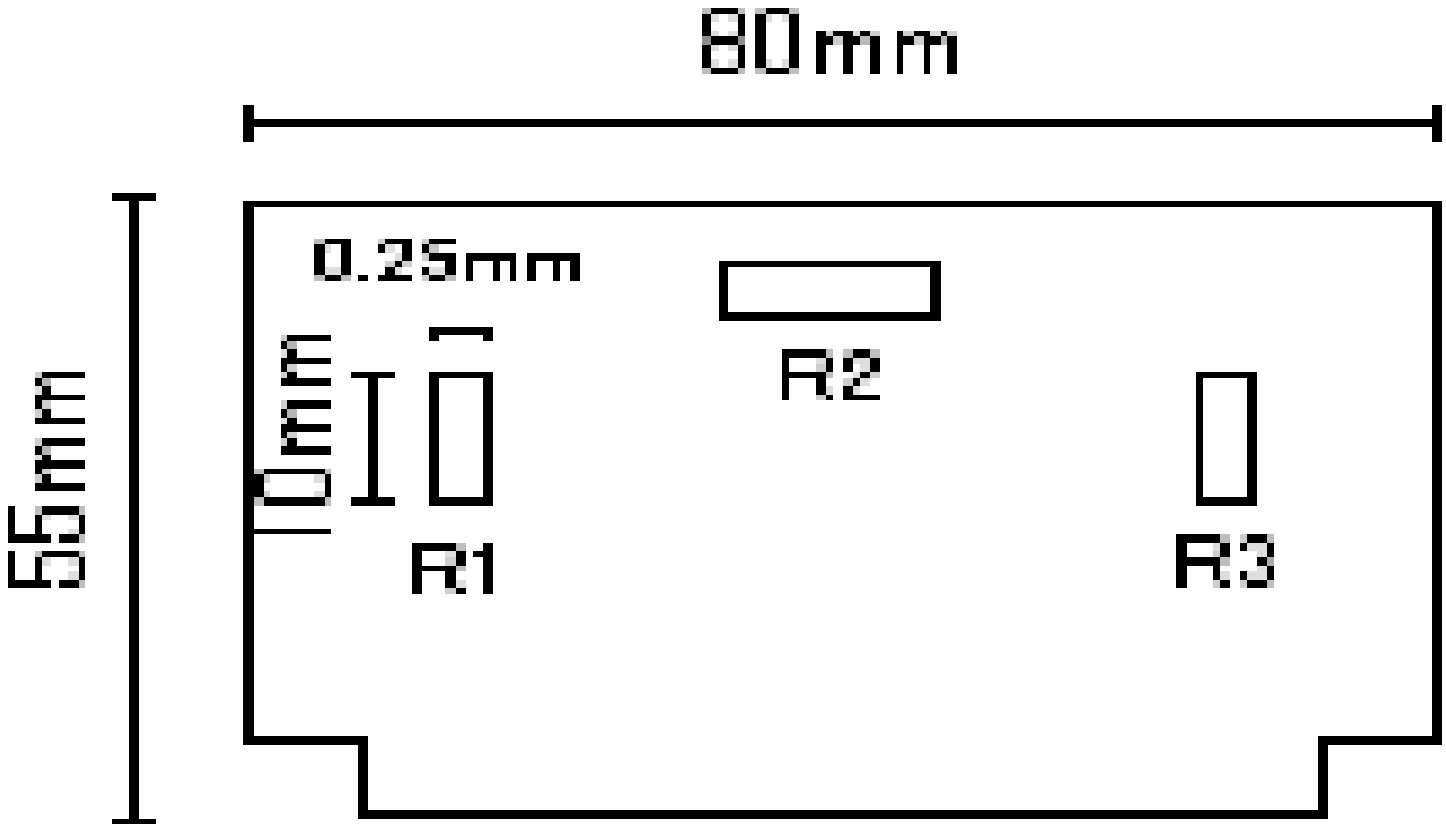
In this study, by using both FEMLAB and the Thermography, the thermal pattern was analyzed of thermally stressed printed circuit board along with the deformation pattern by using the Holographic Pattern Measuring System (HPMS).

Test Sample of PCB and Mounted Devices



- Material of PCB :
  - Paper epoxy resin
- Size of PCB :
  - 80×55 mm
- Mounted Device:
  - Three resistors
    (100Ω, 1/4W)
  - One IC

Model of PCB Surface for Simulation



Condition of Simulation

Simulation Soft-wear：FEMLAB

Current flow to resistors：

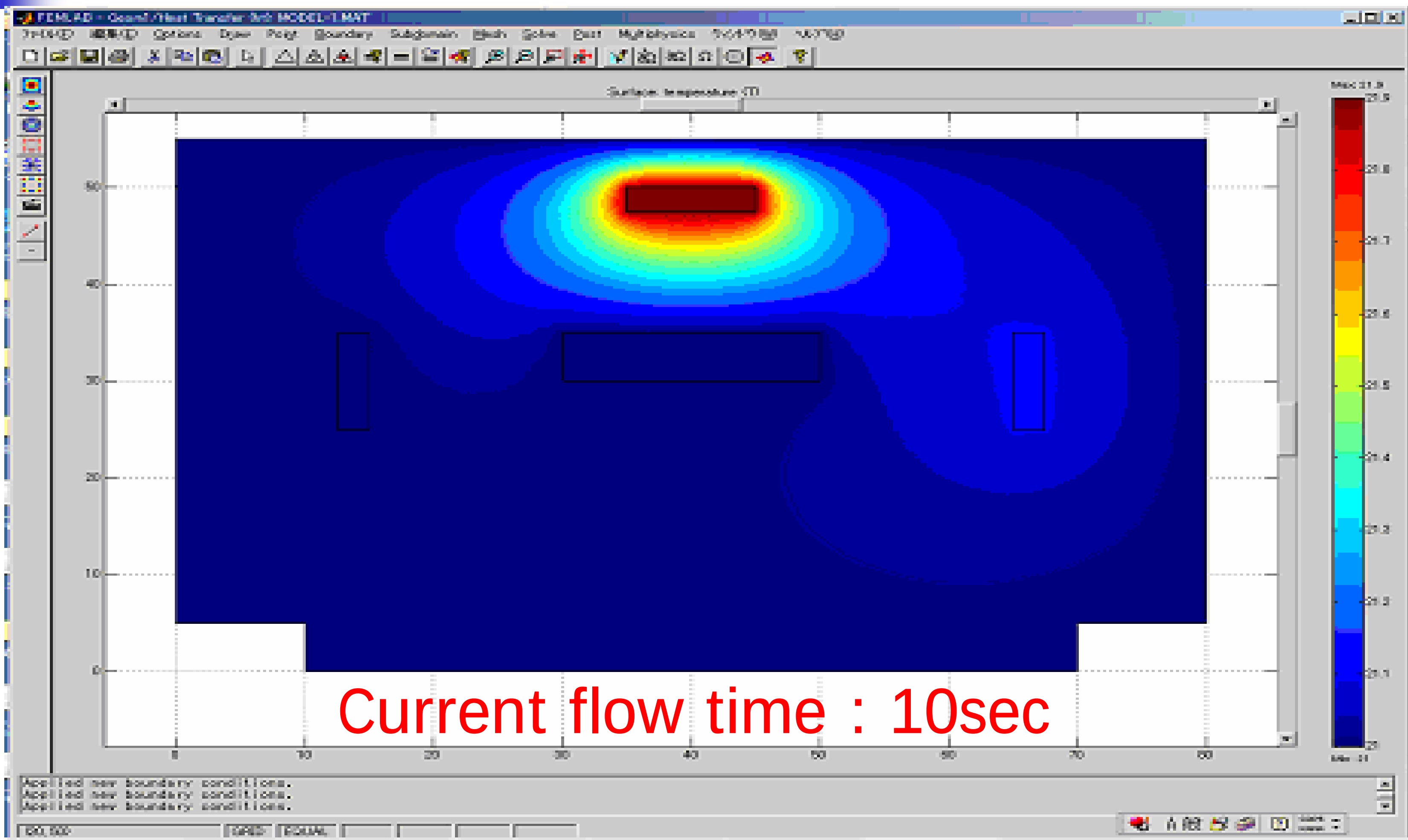
１２V　４００mA　３００Ω

Ｒ１：１００Ω、Ｒ２：１００Ω、Ｒ３：１００Ω

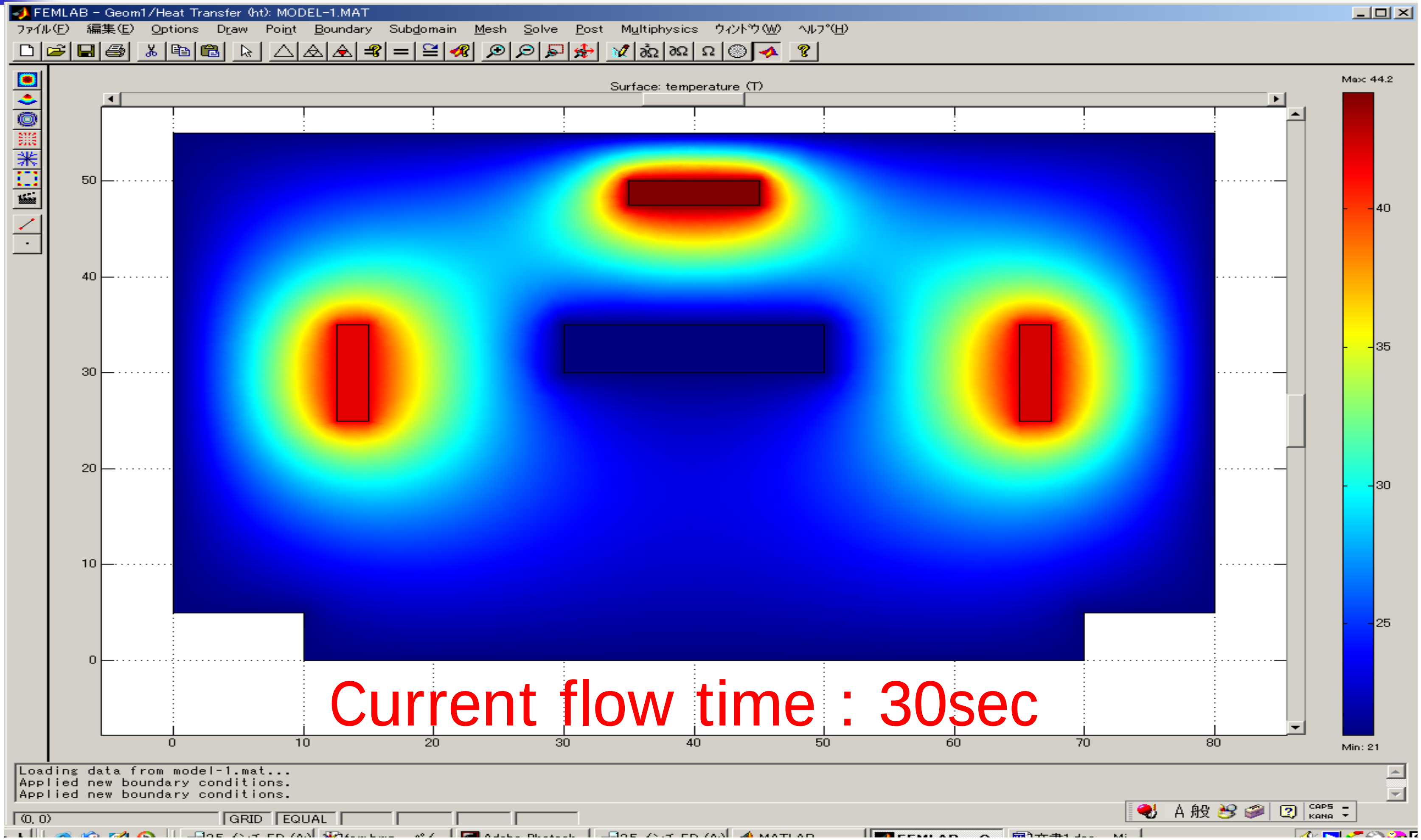
Current flow times：

１０sec、３０sec、60sec、1２0sec

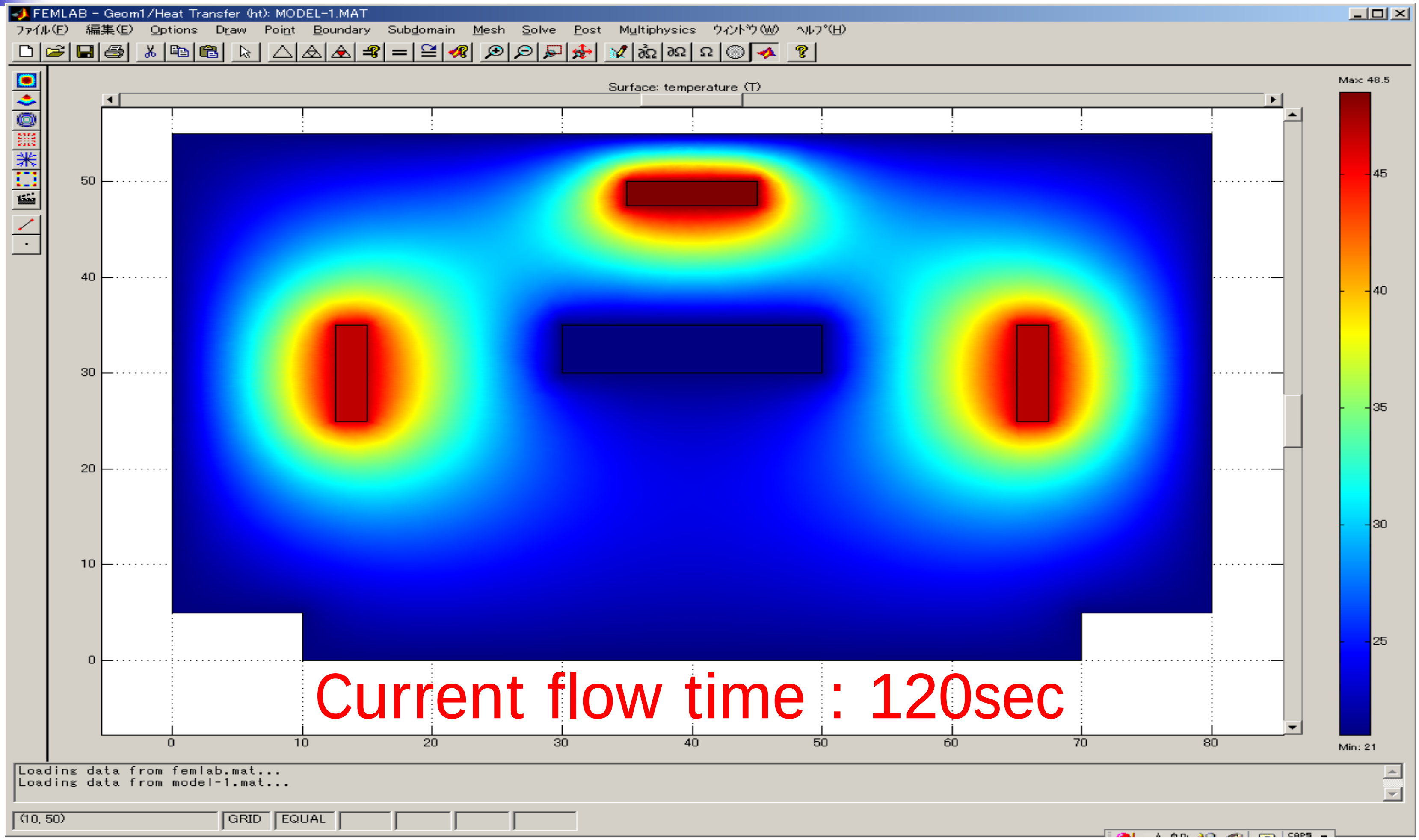
Thermal Pattern on PCB surface by using FEMLAB



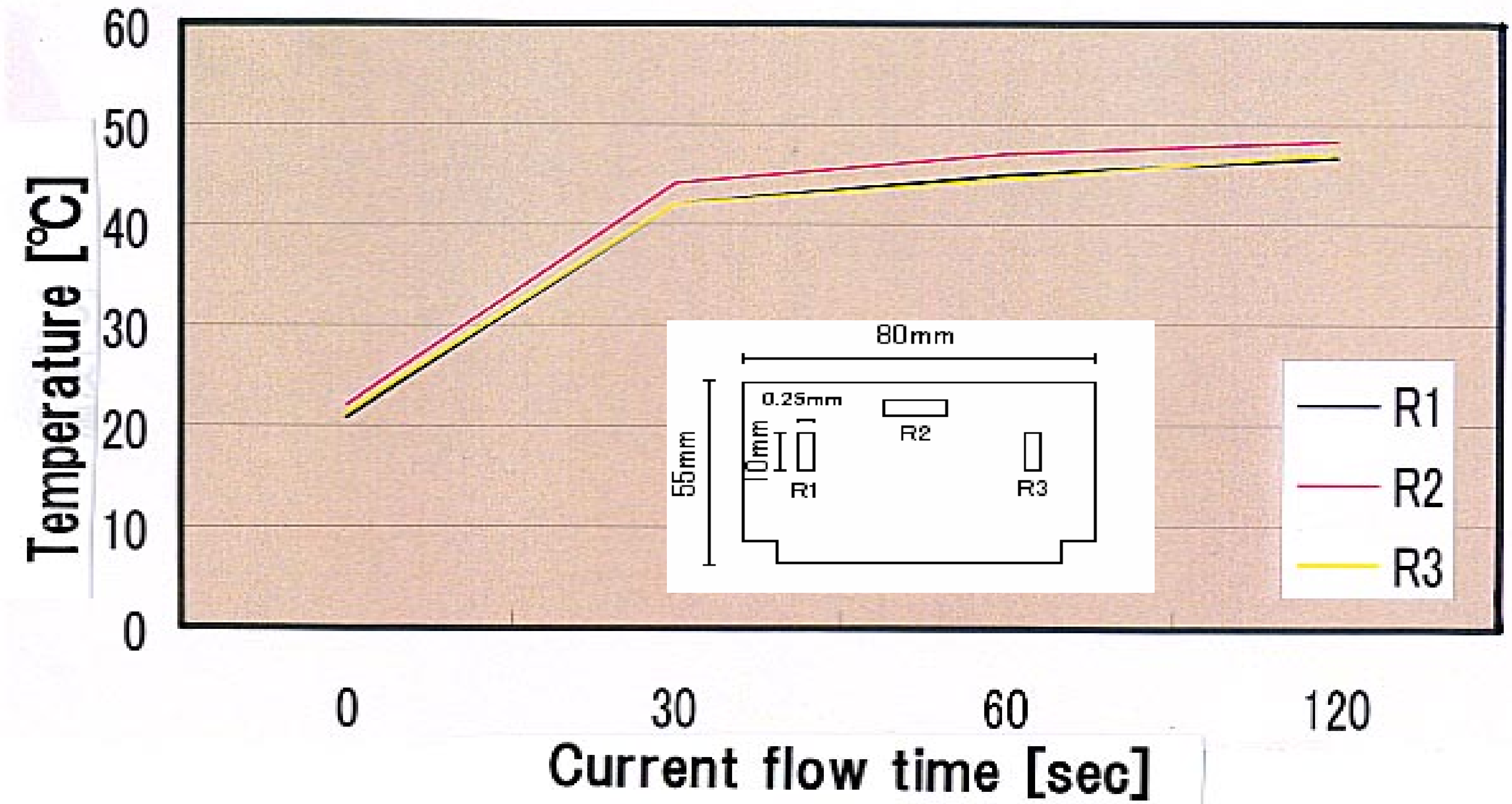
Thermal Pattern on PCB surface by using FEMLAB



Thermal Pattern on PCB surface by using FEMLAB



The Current flow time and Temperature on the resistor surface by using FEMLAB



Condition of Thermal Pattern Measurement

Thermal image measuring system：

Therography NEC TH3104MR

Measuring condition：

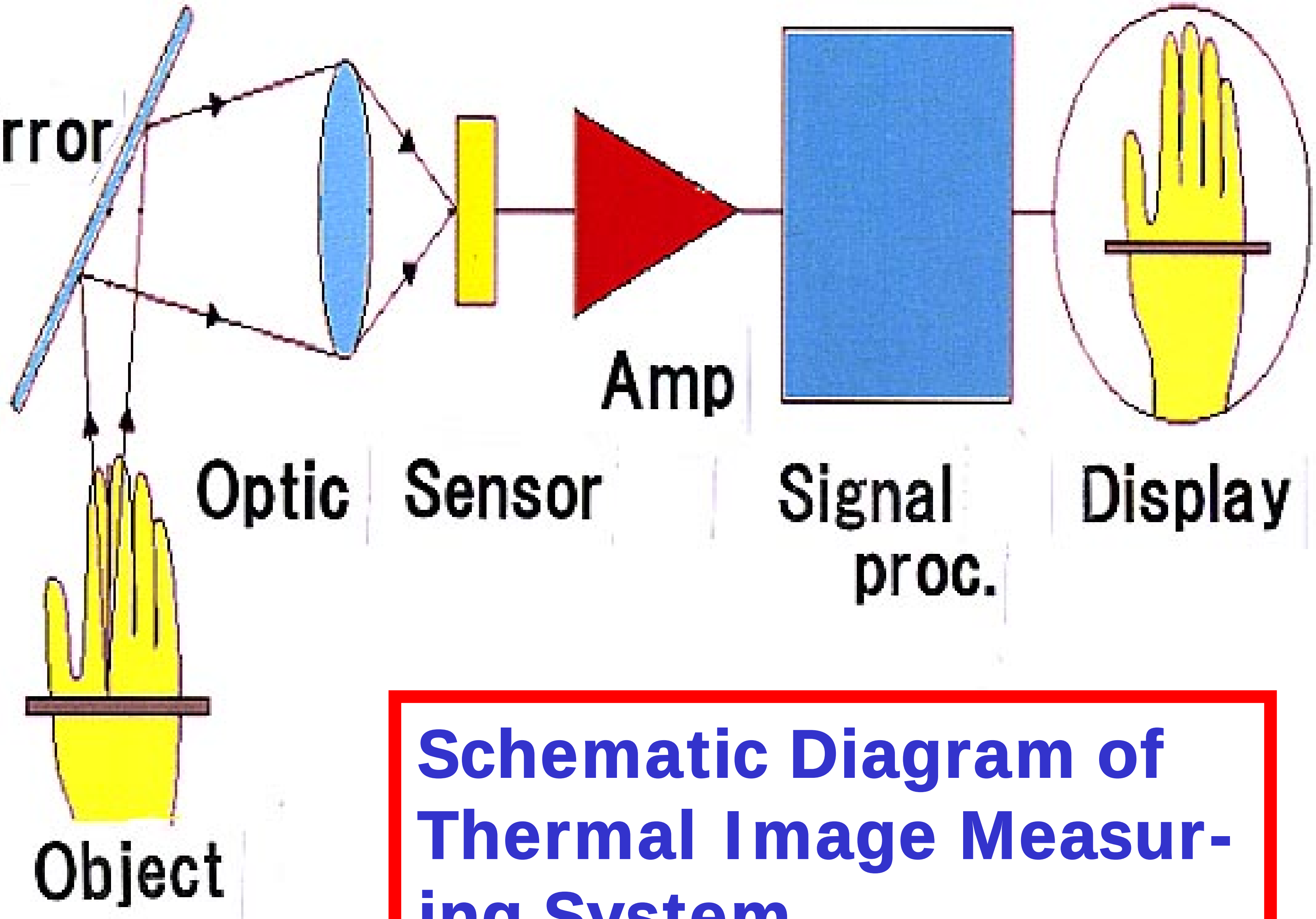
Room temperature：21℃、

Room humidity：50%

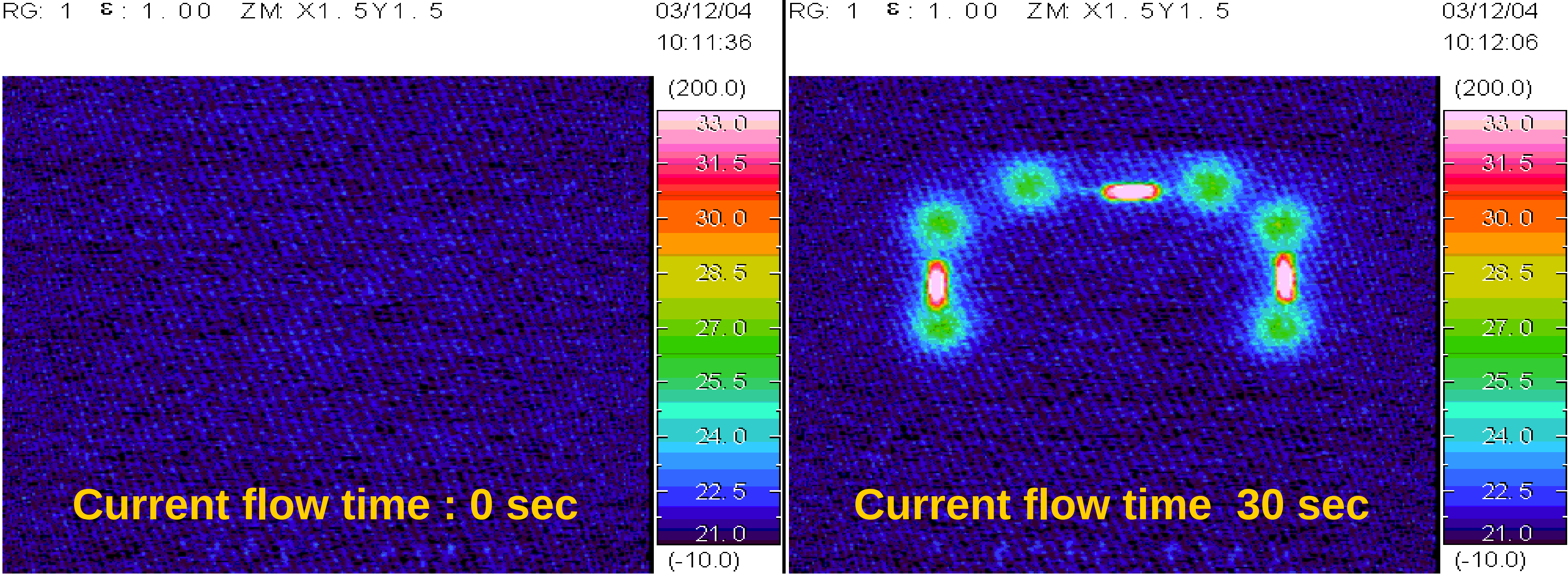
Current flow in three resistors：

DC400mA

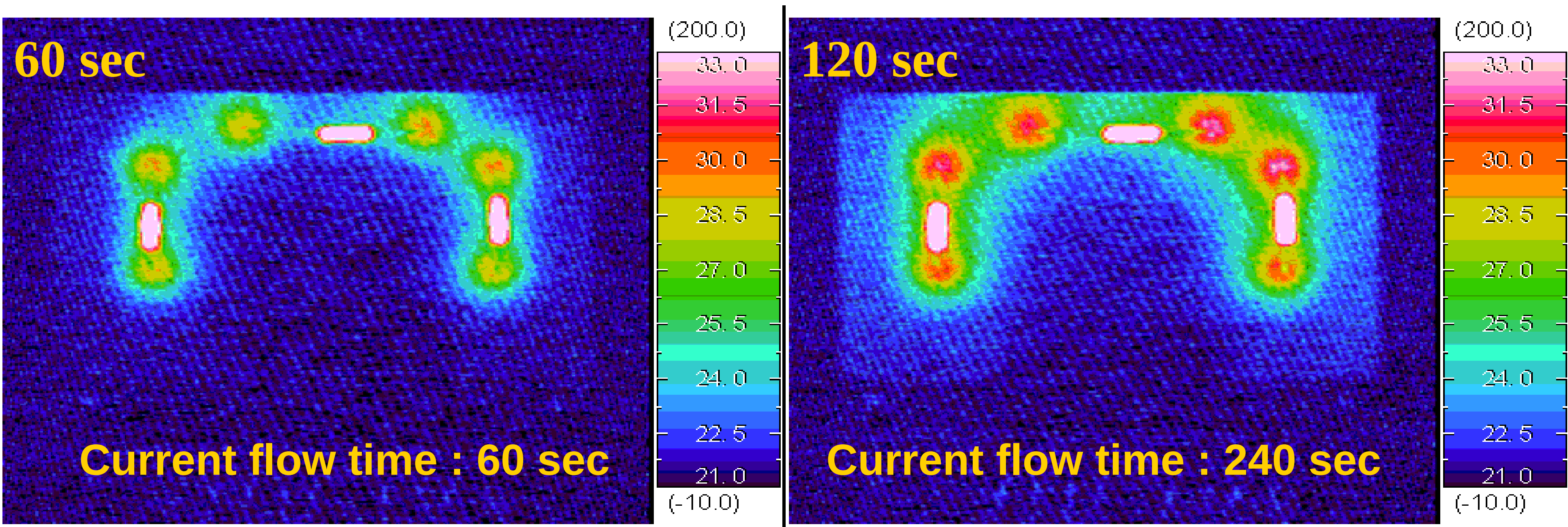
Current flow time：0 ～ 240 sec



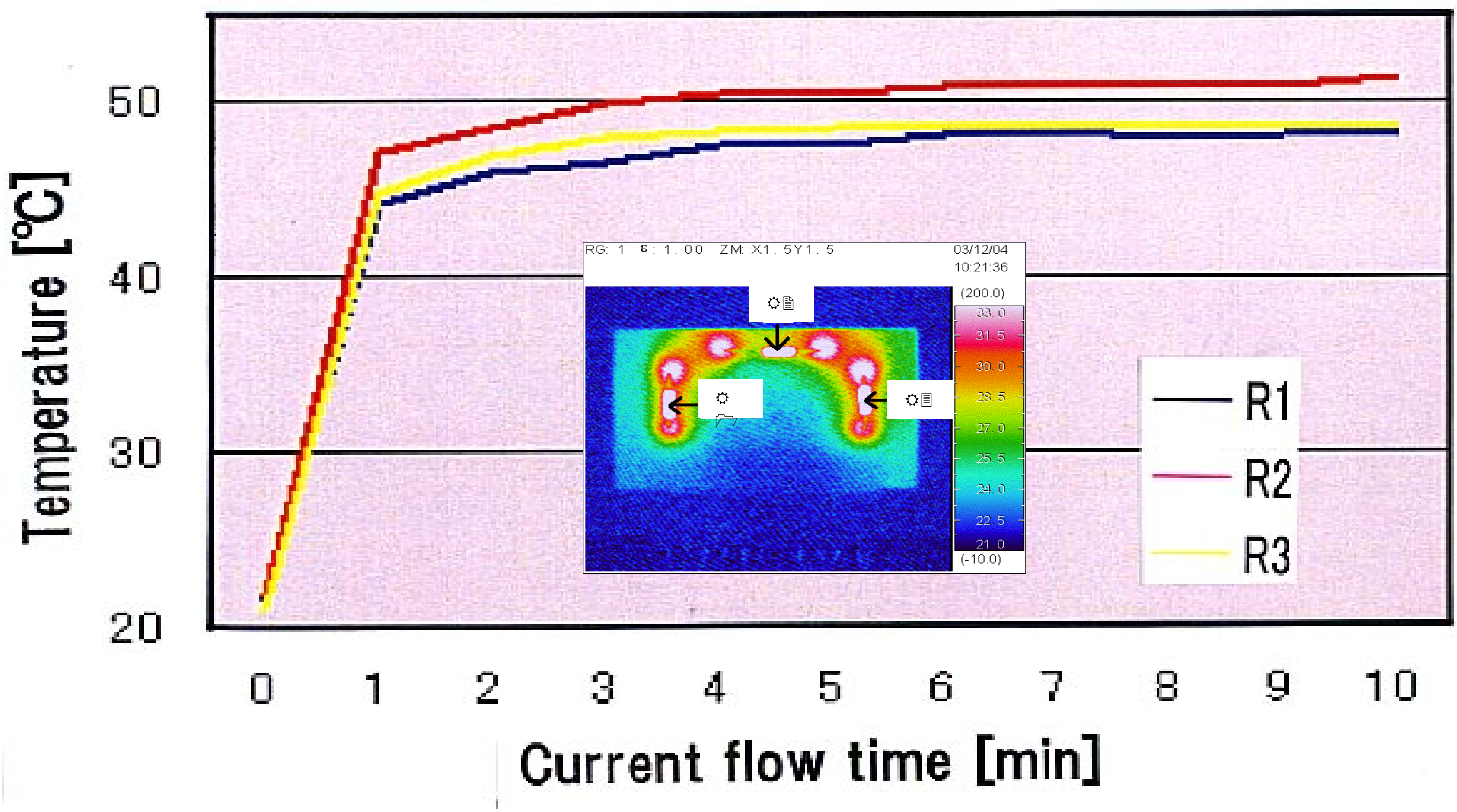
Schematic Diagram of Thermal Image Measur-ing System

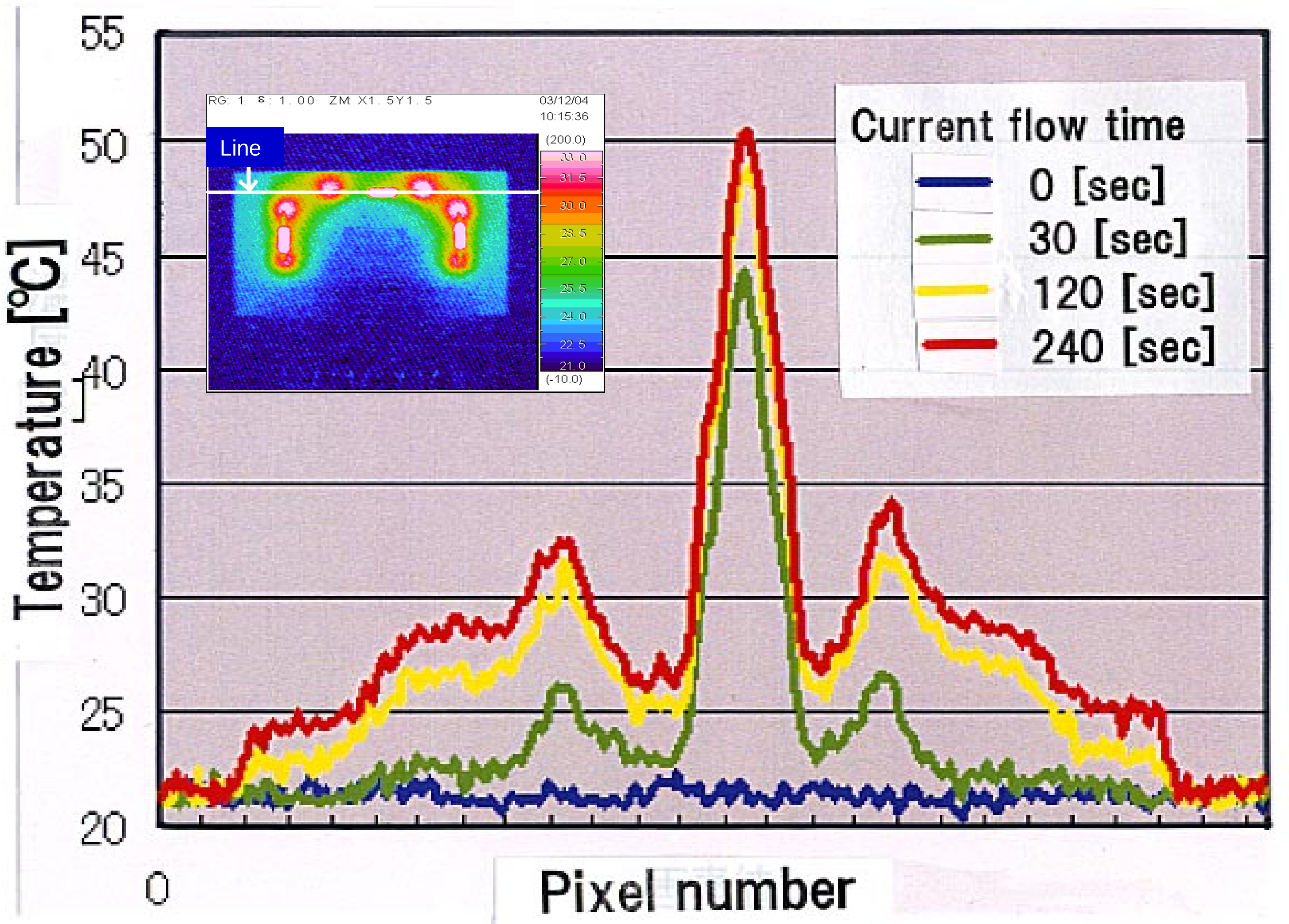


Thermal Pattern of PCB Surface by using Thermography

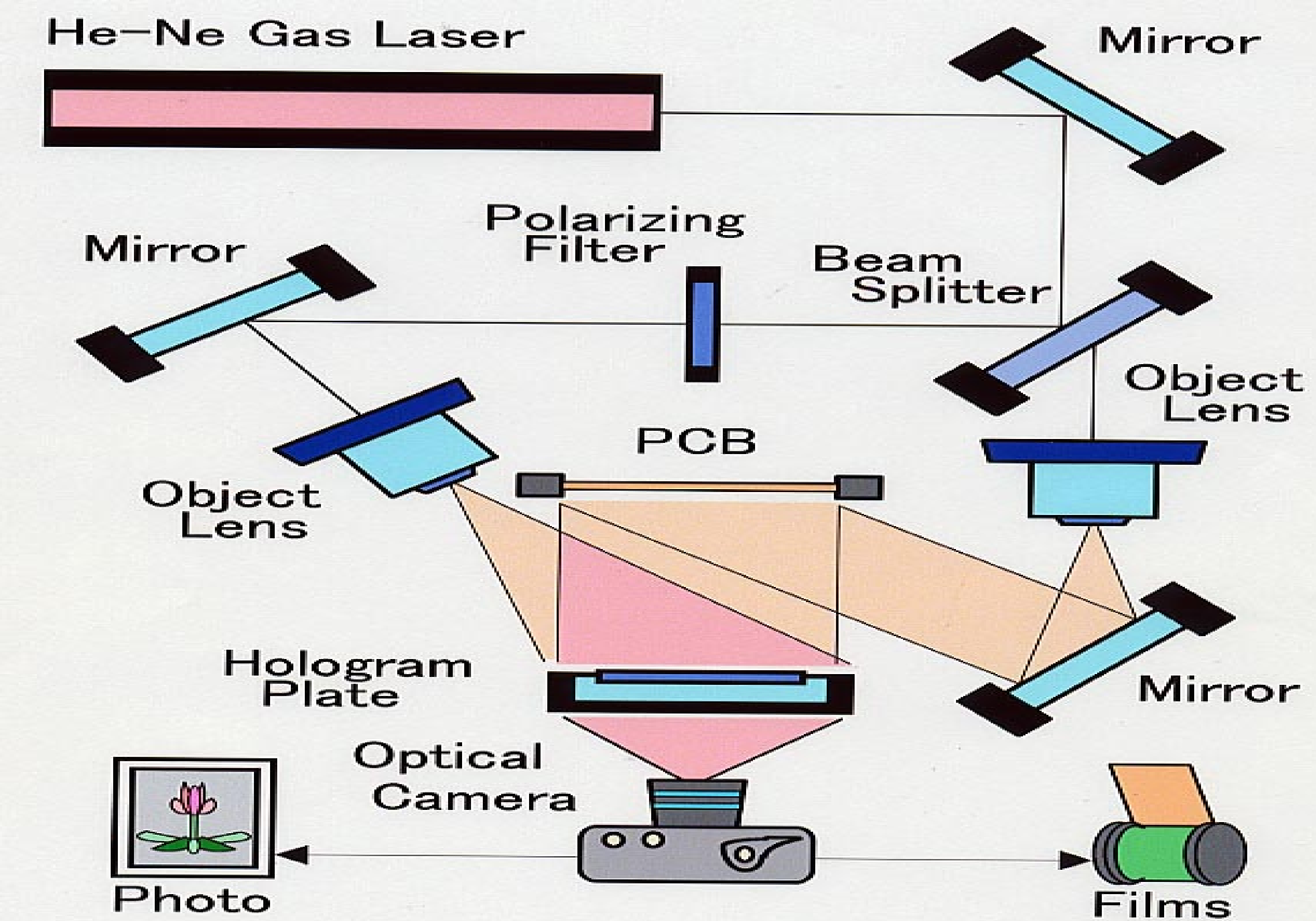


The Current flow time and Temperature on the resistor surface by using Thermography

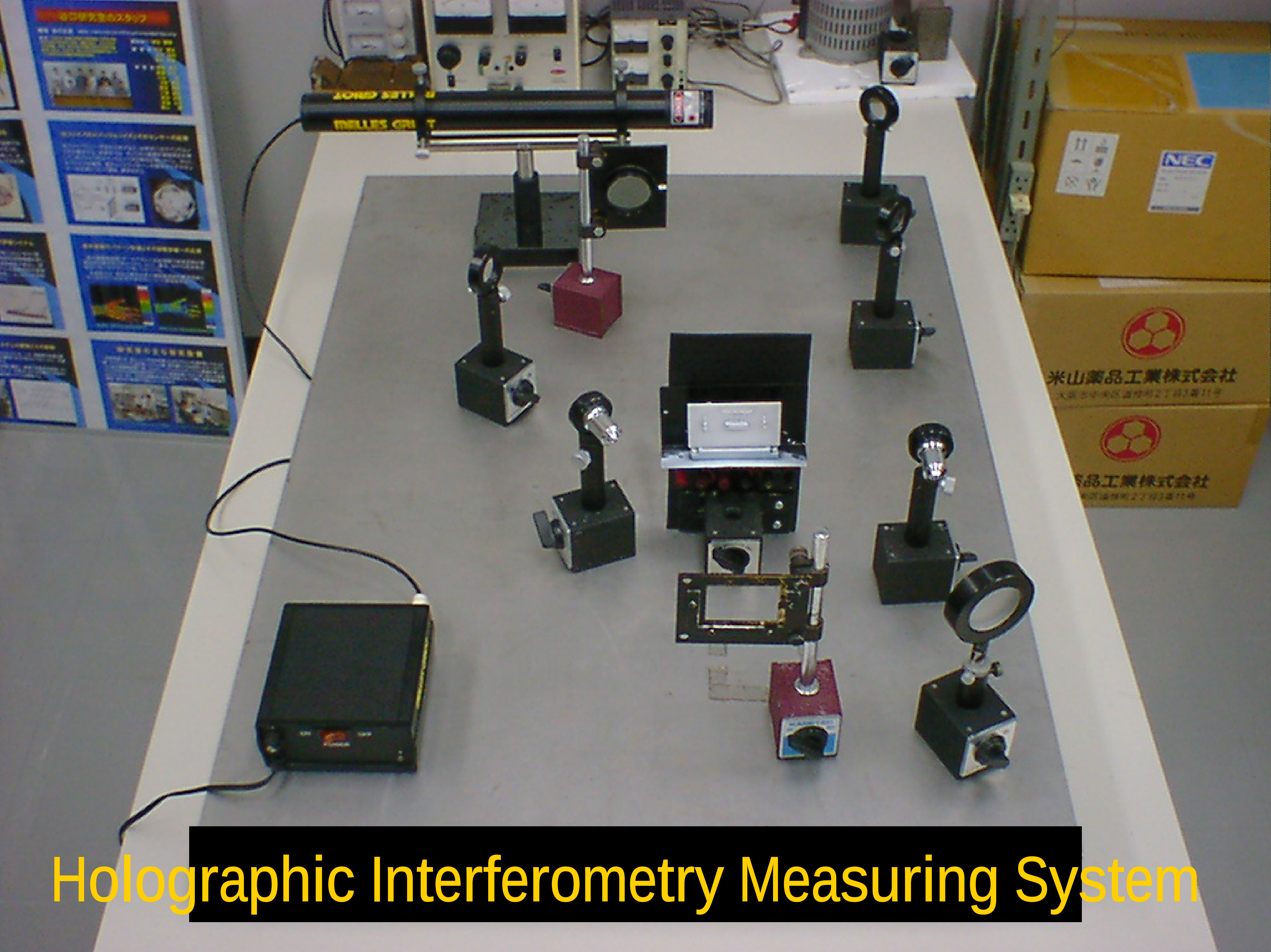




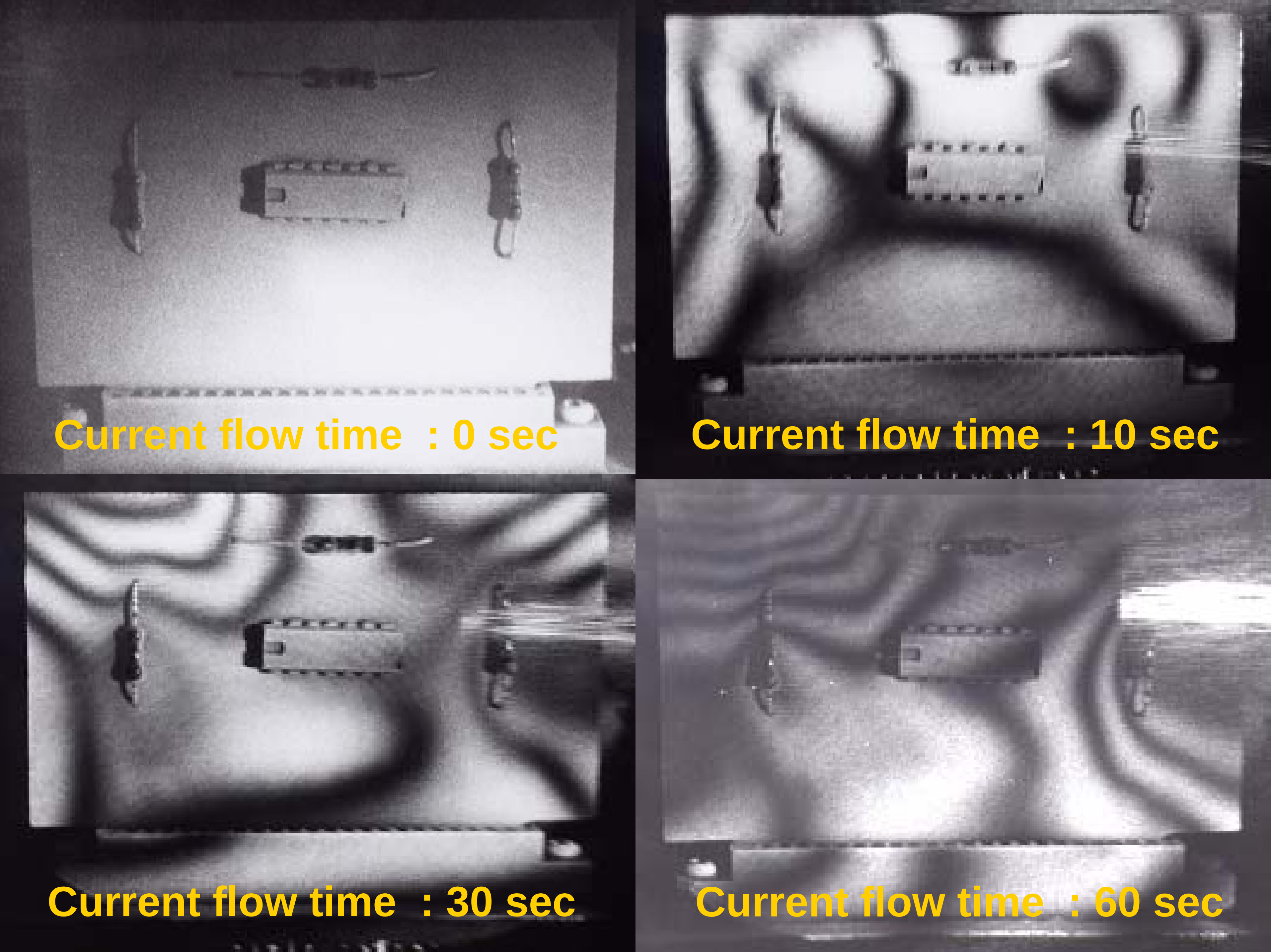
Temperature [°C]
55
50
45
40
35
30
25
20
0
Pixel number
RG: 1 ε: 1.00 ZM: X1.5Y1.5
03/12/04
10:15:36
Line
(200.0)
33.0
31.5
30.0
28.5
27.0
25.5
24.0
22.5
21.0
(-10.0)
Current flow time
0 [sec]
30 [sec]
120 [sec]
240 [sec]

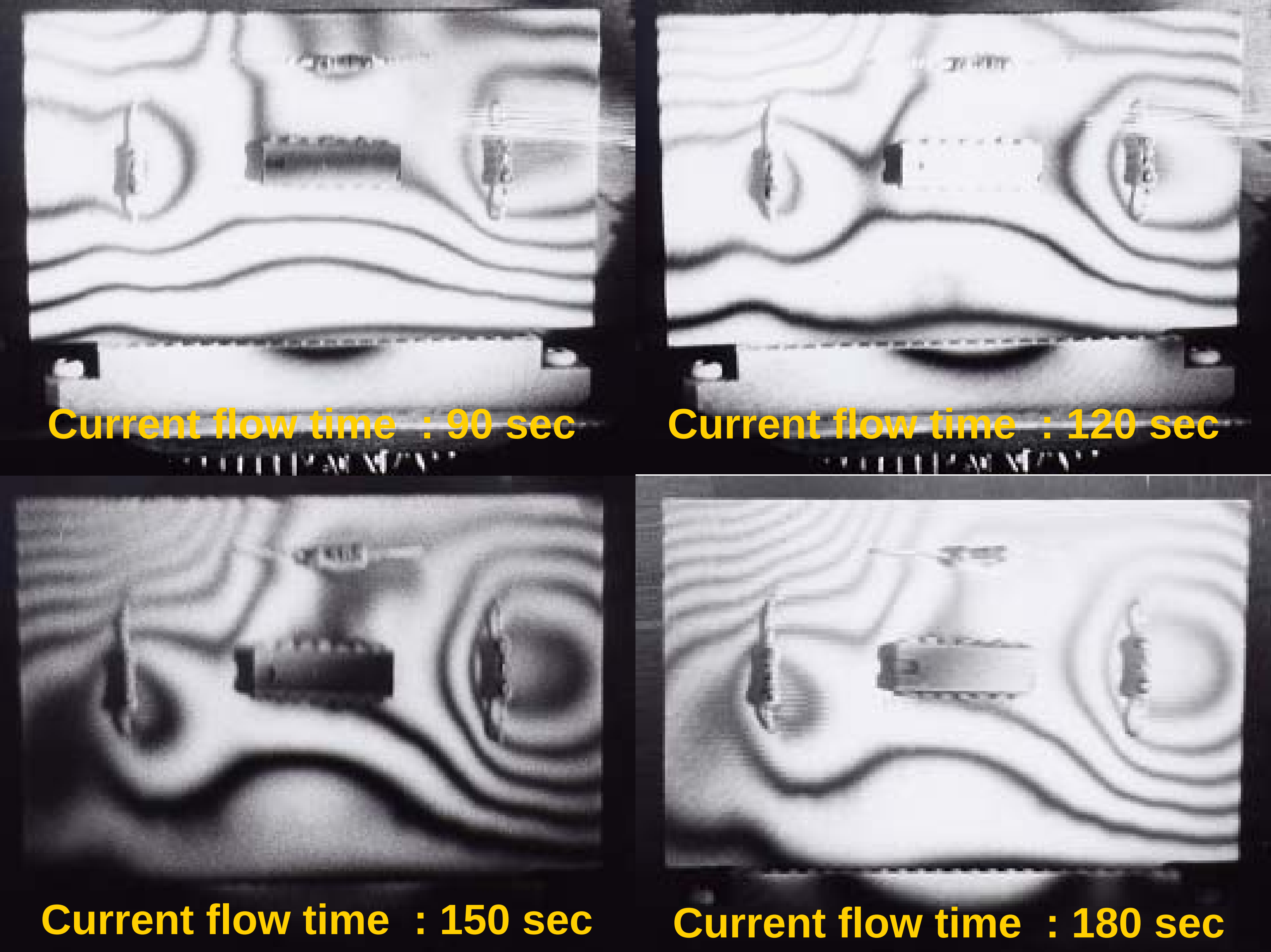


Holographic Interferometry Measuring System

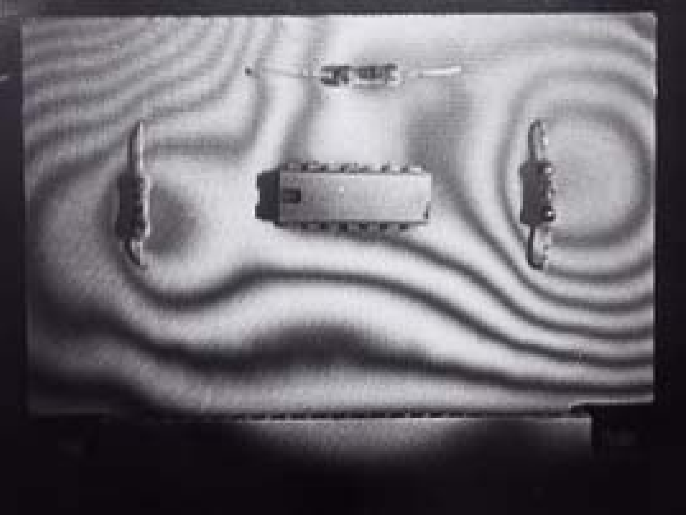


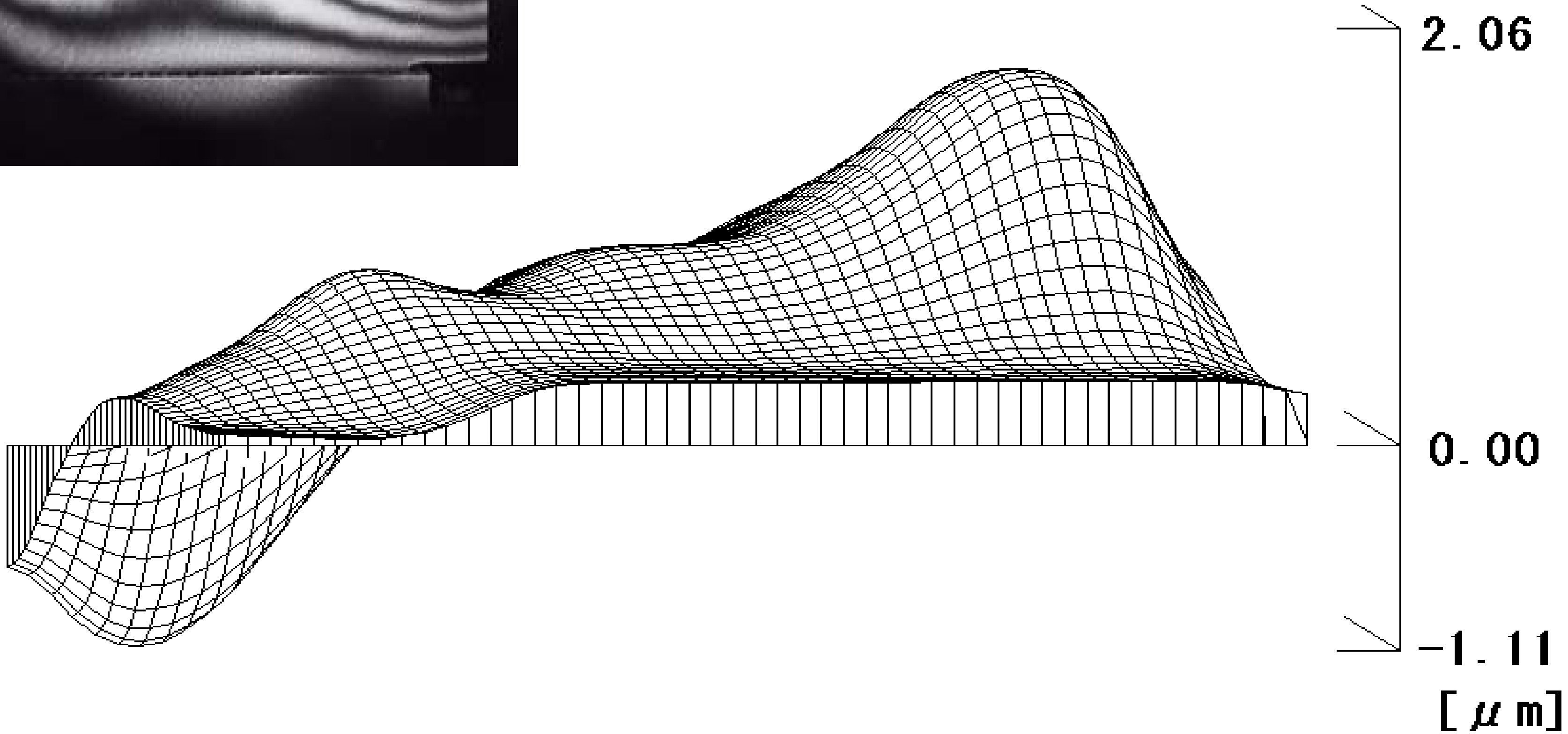
Holographic Interferometry Measuring System


Current flow time : 0 sec
Current flow time : 10 sec
Current flow time : 30 sec
Current flow time : 60 sec

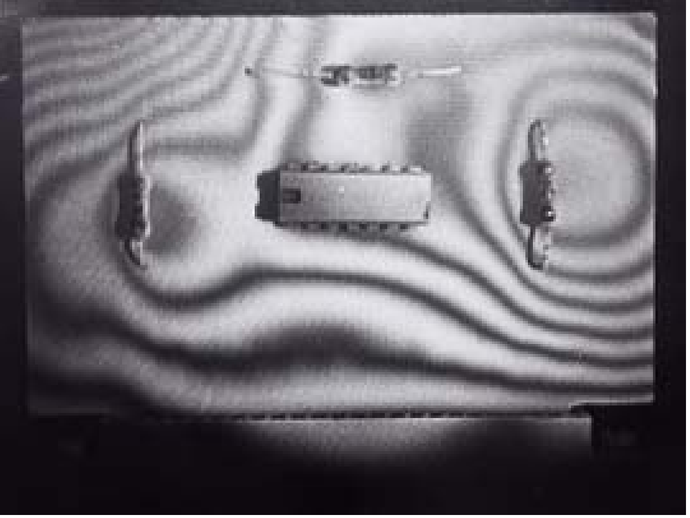

Current flow time : 90 sec
Current flow time : 120 sec
Current flow time : 150 sec
Current flow time : 180 sec

Current flow time 240 sec

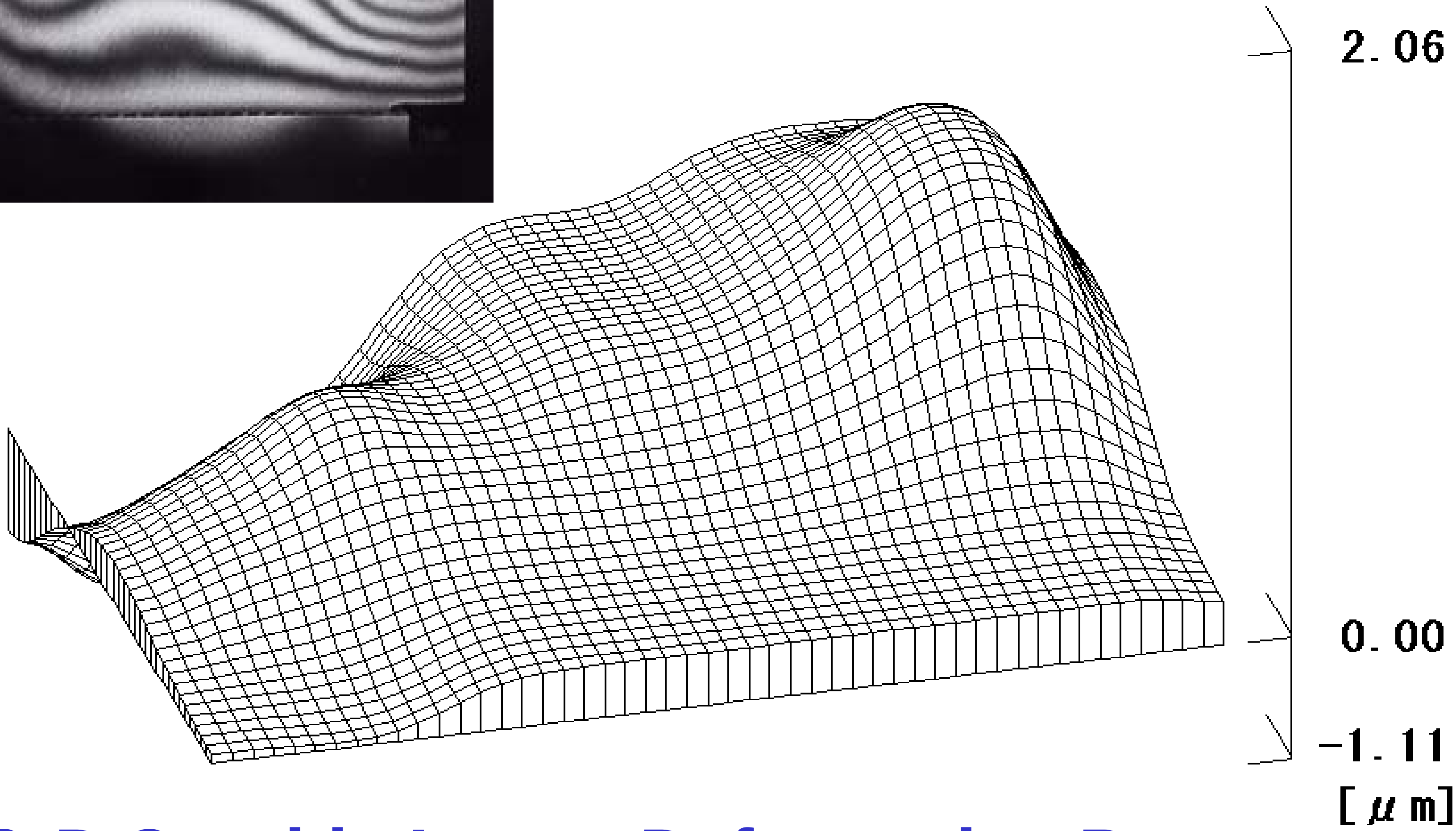




3-D Graphic Image Deformation Pattern of PCB Surface due to Thermal Stress



Current flow time 240 sec



3-D Graphic Image Deformation Pattern of PCB Surface due to Thermal Stress

Conclusions

In this study, the thermal image measuring technique and FEMLAB simulation technique was used to evaluate deformation of a PCB surface due to thermal stress.

In addition, for quantitative measurement of microscopic displacement and its 3-D graphic image, a Holographic Measuring System (HPMS) was applied to the analysis of deformation of PCB resulting from heat generated by the mounted resistor and deformation pattern were obtained.

As the results, the deformation pattern was compared with the thermal pattern. Therefore, we could not image the deformation pattern from the thermal pattern because both patterns are quite different each other.

Thus is order to analyze the deformation of PCB, we conclude that the HPMS is the one of the best methods for such proposes.